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STATUS OF THE HUBBLE SPACE TELESCOPE

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

SECOND SESSION

ON

THE STATUS OF THE HUBBLE SPACE TELESCOPE

JUNE 29, 1990

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STATUS OF THE HUBBLE SPACE TELESCOPE

FRIDAY, JUNE 29, 1990

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:35 a.m. in room SR-253, Russell Senate Office Building, Hon. Albert Gore (chairman of the subcommittee), presiding.

Staff members assigned to this hearing: Steve Palmer, senior professional staff member and Louis Whitsett, minority staff counsel.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. The Subcommittee will come to order.

I would like to welcome our witnesses and our guests here today.

Two days ago, a very dark veil fell on the world of astronomy and astrophysics research. Years of hopes and dreams were crushed by news that the Hubble Space Telescope had a major design flaw, rendering useless some 40 percent of its intended capabilities, and rendering the possibility of conducting significant scientific work almost moot, according to some of the scientists involved in the project.

Engineers at the National Aeronautics and Space Administration announced that they had identified a distortion in one or perhaps both of the mirrors used to focus light aboard the orbiting observatory. This distortion has currently rendered the workhorse Wide Field and Planetary Camera, and the Faint Objects Camera essentially worthless. It means that the telescope's mirrors now focus less than one-third of the light called in NASA production specifications.

At best, that gives the Hubble double vision. At worst, it could mean that a great deal of taxpayer money was handled with less than full care and competence.

I am relieved to know that other instruments, including those capable of collecting light not seen by the naked eye, such as ultraviolet light, are functional and can accomplish the science sought by that segment of the research community.

But I am extremely dismayed by the fact that the Hubble Space Telescope, which has been the dream of scientists since the late-1940s, which has been under development for 12 years, and has cost more than $2 billion, simply does not work. While there still may be avenues that can be taken to make it operable in the short term, it appears that we may have to wait another three years until the first scheduled servicing mission is to be launched in 1993.

Let me make it clear that I remain a very strong supporter of the current management team at NASA. I think they are doing an excellent job. But I am extremely concerned by the fact that after spending almost $2 billion over a 12-year period, we only now find out that this kind of mistake could occur, that NASA did not test the two mirrors in conjunction with each other, as they are normally used, prior to putting this instrument into orbit.

There are a significant number of questions that the Subcommittee intends to address here today. The most obvious that comes to mind is why did not NASA or the contractors responsible for constructing Hubble perform that complete range of tests before the launching last April.

I know that each of the mirrors were tested individually, but NASA apparently considered it too expensive to test those mirrors in combination. But was every possibility pursued? And was that decision to forego testing penny-wise and pound-foolish?

What relationship does this failure bear to the decision by NASA management a decade ago to almost destroy the quality control personnel and capabilities within NASA? What relationship does it bear to the discovery this morning that Atlantis has a major fuel leak, apparently identical to the kind found in Columbia a short time ago?

What are the implications of these repeated errors for the ambitious program NASA has mapped out for the 1990s?

NASA is currently pursuing a very ambitious agenda for the decade to come, which will require a high level of public confidence in NASA's ability to get the job done. This kind of mistake does not enhance the public's level of confidence about NASA's ability.

Any doubts about NASA's ability to manage the space program must be resolved before we can be secure in providing the many tens of billions of dollars that NASA is seeking to complete its present agenda. For there are a number of critically important missions now either in planning or production, including the Space Station Freedom, the Earth Observing System, and the Advanced X-ray Astrophysics Facility, another of the Great Observatories that will employ mirrors for astronomical research.

It is ironic that, as NASA said it did not have the money to have a full test of the Hubble before it was put into orbit, it simultaneously proposes embarking on a $500 billion program called the Moon-Mars Mission.

Today, we thus embark on our effort to determine what has happened and what must be done to restore the public's full confidence in NASA. To help us accomplish this, we are fortunate to have with us Dr. Len Fisk, NASA's Associate Administrator for Space Science and Applications. And he is joined by a number of other officials from NASA.

We will then ask that he be joined at the witness table by Dr. Peter Stockman, who I see is here now. Thank you. Dr. Stockman is Deputy Director for the Space Telescope Science Institute in Baltimore, which is the center for analysis of Hubble data.

Let me say one other thing before closing this opening statement. The Subcommittee formally requested that the contractors responsible for building and testing the Hubble Telescope also join us this morning to be available to answer questions about exactly what has happened. I am extremely disappointed that the two contractors have refused to come forward and participate in this hearing today.

I am also extremely concerned and somewhat surprised that NASA informed the Subcommittee, I am advised by staff, that they would not appear if the contractor representatives were present. I do not understand. Both the contractors

and NASA should be reminded that the $2 billion for this project was not provided out of the executive branch's discretionary funds. It came from the American people. And the elected representatives of the American people have a right to ask for an accounting.

After spending $2 billion for 12 years, to have this kind of unexpected, very large mistake take place, I find it rather astonishing that those who spent the money would not be willing to come before elected representatives of the people charged with the specific responsibility of inquiring as to how the money was spent, and answer questions designed to help illuminate exactly what has gone wrong.

So I would like to note formally for the record that representatives from Lockheed flatly refused to appear here today. Representatives from the chief subcontractor responsible for the work, Hughes-Danbury, advised us that they made unsuccessful efforts to locate someone who was competent to be present and answer questions.

I will pursue with Dr. Fisk the truly astonishing report that NASA itself indicated that it would refuse to come if the contractors were here. I think that is extremely unfortunate, as I said earlier. I have asked the staff to set in motion preliminary proceedings to issue formal subpoenas. I cannot believe that will be necessary, but we are left with no choice. We will not do that this morning, but we will establish a new date for a follow-up hearing, immediately after the congressional recess for the 4th of July, which technically begins today, to hear representatives of the contractors, and witnesses from NASA, to further pursue this matter.

Before concluding, let me express my appreciation to the Chairman of the full committee and the ranking minority member of the full committee, and Senator Pressler, the Subcommittee's ranking member, for moving quickly to allow this hearing to be scheduled prior to the congressional recess. Without their cooperation we would not be here today. I do think it is essential to act in a timely fashion to understand the problems associated with Hubble, as well as to begin taking the necessary steps to determine appropriate solutions.

I have a statement that Senator Hollings would like to have included in the record.

[The statement follows:]

OPENING STATEMENT BY THE CHAIRMAN

When the Congress debated the need for a space-based telescope in the late-1970's, I joined the ranks of supporters because of the obvious benefits that such a platform would provide. According to NASA, an orbiting space telescope should be capable of providing a view of the universe 10 times better than our best telescopes on the Earth's surface.

Today, like nearly everyone in this room, I am upset and disappointed by news that the Hubble Space Telescope will be functionally blind for the next three years. It is serious a blow to astrophysics research throughout the world, to the U.S. space program, and to NASA itself. Because of the Commerce Committee's interest in each of these areas, it is therefore imperative that we gain a better understanding of what has happened and what can be done to repair the damage.

It is a tragedy that after 12 years and spending $1.6 billion on the development, integration, and testing of the Hubble, such a flaw could have gone undetected. Of course, we don't yet know what the precise cause of the problem is, but indications are that it is related to the mirrors and their inability to focus light from distant stars.

This hearing will enable the members of this Committee to question those responsible for the Hubble Space Telescope within NASA, as well as those researchers who are waiting for the opportunity to put the Hubble to work. For there are a great many questions that must be resolved—questions relating to manufacturing processes, technical expertise, management of resources, and perhaps most importantly, possible solutions.

Very simply, we cannot accept the loss of 40 percent of the scientific capability of the $1.6 billion Hubble Space Telescope. The problem must be fixed.

To his credit, Admiral Truly has acted quickly to appoint a Board of Inquiry to investigate how such a mistake could have occurred. And, the Chairman of our Science, Technology, and Space Subcommittee, Senator Gore, deserves credit for calling today's hearing. It is now our responsibility to work together to solve the problems encountered with the space telescope. As Chairman of this Committee, I intend to work toward that objective.

Before concluding, let me thank Dr. Fisk from NASA, and Dr. Stockman from the Space Telescope Science Institute in Baltimore, for appearing today. There was little advance warning for the problems that have developed, but I believe these are the two people who know best what the situation is, as well as the options we have for making Hubble completely functional. Welcome.

Senator GORE. Now our first witness is Dr. Len Fisk, who is the person at NASA with line responsibility for this project. Because of the rather short notice involved in scheduling this hearing, we have waived the requirement that witnesses have formal written statements, 24 hours in advance of the hearing.

We are going to invite you, Dr. Fisk, to present your testimony orally. We appreciate you bringing a model of the space telescope to further illuminate the testimony you are going to give. But, before you begin, I would like to ask

STATEMENT OF LENNARD A. FISK, Ph.D., ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE SCIENCE AND APPLICATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY DR. ED WEILER, PROGRAM SCIENTIST, HUBBLE SPACE TELESCOPE; AND DOUG BROOME, PROGRAM MANAGER

Dr. FISK. To my left here is Dr. Ed Weiler who is the Program Scientist for the Hubble space telescope. And to my right is Doug Broome, who is the program manager for the Hubble Space Telescope. And as you noted earlier, Pete Stockman is the Deputy Director of the Space Telescope Science Institute in Baltimore.

Senator GORE. If you could move the microphone a little bit closer, we will be able to hear you better.

Dr. FISK. Is that better?

Senator GORE. Much better.

Dr. FISK. Senator, what I thought I would do today—this is obviously an informal discussion because I have neither direct testimony to read nor submit to the record as you noted—I want to spend a few moments trying to describe to you what it is we know at the moment about the Hubble space telescope, what is our concern. And of course that raises then three immediate questions. And I want to go through each of them, in turn.

The first question is how did the problem occur in the first place and what we are doing to try and find that out. The second question is what is the impact on the science for having such a problem. And I will try to walk you through that as to what we know at the moment. And the final question is how do we correct the problem to get the Hubble space telescope back to its full specs. And I will try to describe what we again know about that.

Now I hasten to add that we have what we think is reasonably certain evidence of this problem. There are still a few more tests left to be done, but we believe we have the problem at least to the 90 percent certainty level at the moment. That confirmation came over the weekend. We talked about tests which occurred last Saturday and we began to realize the magnitude of our issue on Monday and Tuesday. We are talking about a problem which is now only literally a week old or less.

I am sure that both our understanding of the problem and our understanding of its impacts and the solutions of it are going to change in time as we begin to collect more and more data on this. So I need to preface that in advance because

I think, as NASA always does, we do not try and hide our problems. People know about them when we know about them.

Now, there are disadvantages to that in the sense that we give information out at the stage we understand it at that point. And in a highly technical situation things can, in fact, change.

Okay, let us deal with what the problem is. The problem is called a spherical aberration. There are two mirrors in the Hubble space telescope, the primary which is at the back down here and the secondary which is suspended in the column.

(Indicating.)

The light comes in; it bounces off the primary; it bounces off the secondary; it then goes through a hole in the primary down to where the instruments are.

Senator GORE. And the hole in the primary is right in the center?

Dr. FISK. It is right in the center.

Senator GORE. So the primary mirror is like a doughnut——

Dr. FISK. That is correct.

Senator GORE.——with a small center hole, and the flat surface around the center hole first reflects the light coming into the aperture up to the secondary mirror, which then focuses it through the hole in the center of the primary mirror.

Dr. FISK. That is correct.

In a perfect telescope the light, having gone through that process, the primary, the secondary, down through the hole, would focus at a single precise point. It appears as if the Hubble light does not focus at a single precise point and that, in fact, the light from, let us say, the outer edge of the primary focuses at a slightly different point than the light from the inner surface of the primary. And that is what is called spherical aberration.

Now, the spread here, so we get the kind of distance scales in mind, the distance over which the light is spread, as opposed to being a single precise point, is approximately one-fiftieth the width of a human hair. I mean we are talking about being slightly off here by this distance.

Senator GORE. But that is easily within the range detectable by test instruments?

Dr. FISK. That is correct. The Hubble was to be built to specifications which would have focused light at a point, a distance substantially less than the distance we are off by.

I do need to add, and this is not intended to be an excuse, but in the case of a good ground-based telescope, the kind of scales that we are off by here probably would not be an issue. Hubble was to be built to specifications substantially greater than those of ground-based telescopes.

Obviously, we intended and will get eventually the resolution substantially greater than ground-based telescopes. And we had every intention and are quite surprised by the fact that we have this spread and discrepancy.

Now, the other data point that seems to be significant here is that the spherical aberration is, in fact, very symmetric. You might have said, if you had say a bump in the mirror, a change due to gravity or a change due to thermal problems, then the radiation from the light from one portion, say the top of the mirror, would focus at one point, and the light from the bottom would focus someplace else; but as you went around a single concentric circle here, you know you might have had light focusing in different places.

In fact, as you go around a single concentric circle here, the light focuses all at one point. The difficulty is that for another concentric circle the light focuses at a slightly different point.

Now, what this suggests to people—and I need to emphasize that this is suggest—is that we are dealing with basically a manufacturing or a design defect, because you would not have expected it to be so smooth and so symmetric, if it was the result of gravitational settling, or thermal conditions which were unexpected, et cetera.

Senator GORE. In other words, it is perfectly wrong.

Dr. FISK. It appears to be perfectly wrong. That is correct.

I want to make a point here which I will come back to. That symmetry may actually be the saving grace of this, because to correct for the spherical aberration is, in fact, very straightforward. If the pattern that had been produced on the mirror, was a more complicated pattern, it would be a lot harder to imagine how we are going to make a correction with subsequent instruments. But, in fact, because it is, as you say, perfectly wrong, it is a relatively straightforward matter to imagine how we, in fact, will do the correction.

That is why we are going to express, and I will come back to that, confidence about how with a second generation of instruments this difficulty can be taken out.

Now, the three questions. How did we get this in the first place? The reason that some of us are hesitating to make very definite statements about this is that we are dealing with an event which probably occurred in 1979, 1980, or 1981 when the mirrors were, in fact, built; they were coated and they were declared to be finished.

We have put together a review board, which we call the Hubble Space Telescope Optical System Investigation Board for want of a better name, chaired by and staffed with the best people that I can think of to tell us what, in fact, happened. It will be chaired by Lew Allen, who is the Director of the Jet Propulsion Laboratory, a man I think we would all agree is of uncompromising integrity. And I will announce hopefully later today that people we want will, in fact, agree to serve on this Board. So I decline to give the names of the other members today because we have not confirmed their participation.

But the people that we want on this Board are people who are world-renowned experts in the construction of optical systems who had no direct involvement in the design or the execution of this telescope. I think when you see the members you will, in fact, agree that these people are, in fact, world-renowned experts on this kind of construction. And we are charging them with going back and figuring out what happened in the construction of the mirrors.

Now, how complicated or simple a process that will be, I really have no sense for. If there is one simple explanation, somebody did something, then this will be a straightforward process and that will all come out.

I have to tell you though, I am somewhat concerned that we are going to try and reconstruct an event that took place a decade ago. And, conceivably, you could imagine that there was some systematic error in some piece of equipment that was used in this. Now, our ability to uncover that is going to depend on that piece of equipment still existing after a decade.

We have taken the steps to sequester, impound if you like, the records and the pieces of equipment that exist today that were used in the construction of the Hubble space telescope so, in fact, we can go back and figure out what happened decade ago.

We will move as quickly and as expeditiously as we can in this process. We intend to keep people fully informed throughout the process about what we are doing and how we are going. I am determined that we will get as clean a possible answer as we can out of this on what happened to cause this problem.

But I cannot tell you that I know that today. And I cannot tell you that I know that we should have tested or we did not test. Those are decisions that people made, I assume, wise and valid decisions, or at least logical decisions, ten years ago. We will have to let the review board try and determine what the error in the process was, if any, and give us a clean answer. That is our intention.

I would be happy to pursue that further, but if I may I would like to talk now about the impact on the science for doing this.

As you noted in your opening remarks there is excellent science which is unaffected for all practical purposes by this problem—spectroscopy, ultraviolet astronomy, all of which are main and central goals for the Hubble space telescope.

It is also important to note that there are some aspects of the focus of the Hubble Space Telescope as it exists today which can be exploited very much to our advantage. Normally, when you have a ground-based telescope the signal from it is spread over whatever is the resolution of the ground-based telescope, typically half-an-arc-second or so.

In the case of Hubble, because of the nature of this focusing problem, we produce an unusual signal. We produce a signal which has a very sharp peak at the prescribed resolution of Hubble and in which about 20 percent of the radiation occurs in that peak. As you noted in your earlier remarks, the design specifications said 70 percent of the radiation should occur in that peak. So if you would like to describe this problem, it is in effect that we have created more background noise in the Hubble Space Telescope than was the design spec. We still have a very sharp, high resolution peak with 20 percent of the energy in that peak as opposed to 70 percent. So rather than having 30 percent of the remaining light distributed in the background, now we have 80 percent of the remaining light distributed in the background.

Now that is something you do not get with a ground-based telescope. In a ground-based telescope the radiation is spread out over a much broader signal. As a result of that feature of the signal for any source, which is reasonably bright, for any source which has reasonably high contrast, we will in fact get today the full resolution of the Hubble Space Telescope.

Where we will have difficulty is when we try and look at very faint source, extended sources, or sources which have low contrast associated with them. So that there are many of the objectives in visible light which can be achieved as well, in addition to all the ones in ultraviolet light and all the ones in spectroscopy.

And so what we will do now is adjust the observing program to emphasize the things that Hubble does very well today. We are, as you probably know, very much oversubscribed in the science, we are going to have a lot of happy spectroscopers and happy ultraviolet scientists because they are going to get more time on the telescope than they would have anticipated in a more balanced program.

The next step is to figure out how to correct the problem. As I indicated to you, because of the spherical symmetry of the distortion it is quite a straightforward matter to insert a single lens or correcting mirror into the replacement instruments that are under development for Hubble. And when they are installed on orbit, in 1993 or 1996 in some cases, but 1993 for the one that is most disadvantaged at the moment, the WFPC, the wide field planetary camera, the installation of a single lens in that detector corrects the problem.

It is neither a big cost impact to the development of that instrument, which is in the budget at the moment, nor a particular technical problem. And that is the plan.

We will also ask the obvious question of whether or not we could accelerate the development of the replacement wide field/planetary camera and arrange for an earlier shuttle flight, so that we can recover faster. If you look at the use of the Hubble Space Telescope over the next five or six years, what you will find is that for the next two or three years, we will be emphasizing ultraviolet astronomy, spectroscopy, and for the second-half of that period, after the replacement instrument is installed, we will emphasize the high resolution faint object work.

And so if you look over the entire period, I am very optimistic today that we will have in fact all the science we expected from Hubble, just distributed differently.

I would be happy to try and answer any questions that you have based on what we know at the moment.

Senator GORE. Very good. We will have some questions before we turn to you, Dr. Stockman.

You indicated that the error falls within the specifications for a ground-based telescope. But the specifications for ground-based telescopes are designed with the full knowledge that repair and recalibration are relatively simple matters. That is why significantly higher specifications were mandated for the space-based Hubble, because it cannot be easily repaired and recelebrated. That is why NASA had higher specifications, which, of course, added to the Hubble's cost as well. And the issue involved there is quality control.

This the second time in five years that a major project has encountered serious disruption by an inherent flaw that apparently was built into the project as much as 10 years before launch and went undetected by NASA's quality control procedures. Fortunately, this is not the kind of horrible tragedy that Challenger presented. But it is an inherent flaw that was built into the project and went undetected.

NASA does have other proposals now in early stages of development which will require a decade, and in some cases several decades, of work prior to the performance of the mission in space. So the implications for Space Station Freedom, for the Moon-Mars mission and for other large new missions are really quite significant.

I served on the House Space Subcommittee before coming to the Senate six years ago. We had a hearing back in 1983 with a vice president of the company building Hubble. The company was Perkin-Elmer. It was purchased by Hughes and has been called Hughes-Danbury since the takeover; but at that time it was Perkin-Elmer.

The vice president of that prime subcontractor, John Rehnberg, said the following, seven years AGO. "Our problems resulted"—he is talking about the development was so late, and why it was significantly over budget—"from a combination of underestimating technical challenges and the cumulative effect of funding shortages. This funding shortfall in turn resulted in elimination of development testing, cutbacks on critical support hardware, interruption in certain developmental efforts and general operational inefficiencies."

Seven years ago a spokesman for the contractor principally responsible for this project advised both Congress and NASA that testing was being eliminated, funding shortfalls were having a serious impact on the project, and that there were general operational inefficiencies. Yet NASA continues to ask for larger and larger, more and more expensive new start-ups, even as it scrimps on the ongoing projects and cuts out critical testing designed to give us the level of quality control that the taxpayers have a right to expect.

I am extremely concerned about it. Why were the two mirrors not tested in conjunction with each other in the mode in which they are normally used in space?

Dr. FISK. Senator, I am going to give you the most preliminary of answers because, we should let the experts in optical systems go back and review what happened here.

Senator GORE. Well, let me say there, Dr. Fisk, I listened carefully to your statement about NASA speaking out, even though the understanding of the problem was still in evolution; and I think that is an appropriate word of caution, absolutely. We fully understand that, as you learn more, you should have the right to adjust to your understanding of what you think occurred.

But I am not asking here about what exactly went wrong in the construction of the mirror. I am asking why NASA did not test the mirrors.

Dr. FISK. Let me answer the question as to the question I think I would raise with the people that are going to look at this. I cannot personally tell you how much testing occurred in 1980. I mean, we are all taking a crash course in the history of the Hubble Space Telescope, those of us who are more recent on this activity.

But I think the question that is going to have to be asked Is. was it a reasonable set of tests to do for the complexity and the dollars that would have had to have been spent in order to do that. I mean, that is the question that you have to ask.

If it turns out, as has been suggested—and again I need to have these things validated by people looking at this—that in order to do a test on the Hubble Space Telescope, which has these incredibly accurate specifications, and which is going to work in zero gravity as opposed to normal gravity, and to compensate for the way the telescope appears on the ground versus the way the telescope appears in space.

Let me just divert on that point for a moment. The changes in the mirror shape which could have produced this kind of distortion in the focus at the outer edge of the mirrors is about 8 wavelengths of light, 8 wavelengths of light being 10-6 centimeters. The gravitational change in the mirror, just going between the ground and space, is about 12 wavelengths of light. And so already there is a calculation that has to be done between having the mirror on the ground and having the mirror in space.

Senator GORE. Well, the implication of your statement is that it was impossible to test it before launch. And that is not true, is it?

Dr. FISK. All I am saying, Senator, is that in order to evaluate the testing, whether or not it should have occurred, is whether or not it would have yielded information that was worth the cost and the complexity of doing a test. And I do not know the answer to that today. But that is a question that I expect my review board to tell me yes or no.

Senator GORE. Did Hughes-Danbury make the decision not to conduct that test?

Dr. FISK. I assume they did not in the sense that NASA has control of the project.

Senator GORE. Did Hughes-Danbury or Lockheed have input into the decision not to test the mirrors?

Dr. FISK. Senator, I do not know. I will give you as honest an answer as I can. Neither I nor anyone else at this table was present at that time. And we are going to have to go back and reconstruct the history.

As you probably know that was a very turbulent time in the history of the Hubble Space Telescope. That was the time in which cost overruns were being identified and management difficulties were occurring. And, you know, we are

going to have to go back and look at that time and sort through it. Sitting here today, I do not know.

Senator GORE. It is also hard for you to answer questions that are more properly put to the contractors. Is there an atmosphere of conflict between you and the contractors?

Dr. FISK. I am not aware of one, and I have talked to the senior vice presidents of the various contractors, including, as you note, Hughes, which now owns the facility in Danbury and in all cases they have pledged their support. There is an attitude at the contractor of very much wanting try to and find out what happened.

Senator GORE. You had no objection, then, to being in the same room with them?

Dr. FISK. Senator, I did not. We seem to have had some misunderstanding of that. I objected to the thought that I might end up in some debate with them. I have no quarrel whatsoever if you wish to talk to my contractors.

Senator GORE. Why did you advise the Subcommittee, or why did your spokesman advise the Subcommittee that you would not attend today's hearing if the contractors were present?

Dr. FISK. Again, I think we have had some sort of a misunderstanding. I assumed coming in here this morning that the contractors were going to be here. What I did request, because I am very apprehensive, because I want the review board to be definitive, of trying to speculate what has happened, given how little knowledge at least I and other people have of what happened ten years ago. I want to be sure that I have a clean, definitive review.

Senator GORE. Last night, not on one occasion but on two occasions—and there is no misunderstanding on the part of the Subcommittee. We heard what the English language communicated from your spokesman. On two occasions you had her advise the Subcommittee that if witnesses from the contractors were present you would not appear. Did that get communicated to the Subcommittee without your knowledge?

Dr. FISK. I think we have had a miscommunication, Senator, and I am sorry if that has occurred. I am not going to tell the Congress of the United States who they can talk to, so I assume that if you want to talk to my contractors you should talk to my contractors. The only thing I would not like to do is, because we are so early in this process of unraveling it, trying to speculate on events that happened that really need a thorough investigation. And the one thing I guarantee you is that when we are done with this investigation, nobody will be able to say that we did not overturn and look at and probe every aspect of this problem, because I want to know the truth.

Senator GORE. Well, I can appreciate the desire of NASA that Congress just stay out of it and let NASA be completely responsible for investigating this matter. Again, the money did not come from NASA's discretionary funds or the Executive Branch's discretionary funds, and NASA has repeatedly reassured this Subcommittee for the last 12 years that everything is under control. Just let us handle it. Now that everything is not under control, and a major mistake has been made, again, NASA says let us handle it. You stay out of it.

Now, I still do not quite understand why NASA would say, as it did, do not ask the contractors to come, and if you do we will not show up. I do not understand why that message was delivered to the Subcommittee. Can you help me understand that? You say that it was a miscommunication, and that there is just a misunderstanding involved. The words used were very clear, and were used not on one occasion but on two occasions, and if you tell me that that was done without your knowledge, then I can accept that and will pursue it in other ways, but that is not exactly what you are saying, is it?

Dr. FISK. What I am saying—you and I over the years have had a very honest dialogue with each other.

Senator GORE. Yes, we have.

Dr. FISK. So I am going to give you as honest and straightforward an answer as I can. The only circumstances I would like to avoid is, at this point in the process, where we know so little about what happened back then—at least, I do—that I find myself in some sort of a dialogue, all of us sitting here together speculating on what could have happened, because I have nothing to contribute to that from what I know at the moment.

Senator GORE. Did you authorize your spokesman to say you would not come if the contractors came?

Dr. FISK. The only statement that I think I made, and I do not always speak clearly, is that I did not want to appear at the same table, because I did not know that we could participate in some sort of dialogue. I assumed, until I got here, that the next set of witnesses was going to be my contractors.

Senator GORE. Did you ask the contractors not to come?

Dr. FISK. I have not spoken to any of my contractors.

Senator GORE. Did anyone at NASA ask the contractors to refuse to appear this morning?

Dr. FISK. I have no knowledge of that, but I doubt it.

Senator GORE. Do you think it is appropriate for the contractors to refuse to appear this morning?

Dr. FISK. I think you are more than welcome to speak to the contractors—I really do. But again, all of us are in the process of speculating on what happened as opposed to having gone through some systematic process of trying to figure out what happened.

Senator GORE. Well, the implications of what we were told are that if the contractors had appeared here this morning, and if you had followed through on the statements made twice to us last evening and then refused to appear yourself, this subcommittee would be in the position of issuing a subpoena for the NASA official responsible for spending the taxpayers money authorized by the Congress on the recommendation of this Committee.

That would have been an absurd result, and yet the position you have put us in is one where the people who have important parts of the information on what happened have refused to come, after you made it clear you did not want them to be here. That is why we are going to pursue this.

Dr. FISK. Senator, please bear in mind that there are no circumstances in which I would not appear before this Committee.

Senator GORE. I believe that. That is why I have asked for additional help in understanding why your spokesman would threaten to withhold your appearance in the event that the people who actually built this telescope were here at the same hearing.

Dr. FISK. It is also my expectation, Senator, that as we go through this review process, which we will go as quickly and as thoroughly as we can, that at any point in that review process, night or day, that this Committee or any other Committee wants to know about what we are doing, participate in it, learn about it, that they are more than welcome.

Senator GORE. That is good. I can understand how you would like to design these hearings, as you have designed the telescope, and design exactly who appears and who comes to the table, and who does not appear, but in any event——

Dr. FISK. I trust the hearings will be more in focus, Senator.

Senator GORE. When we get both of the reflectors in line here in the same room.

You are not the personal responsible for what happened, I understand that.

I think it is time to move on.We will have an opportunity to have the contractors and NASA here at the same time at our next hearing on this issue.

Now, what exactly was tested? Were the two mirrors tested individually and then not tested together? That is my preliminary understanding. Is that what you think took place?

Dr. FISK. That is my understanding as well, Senator, that there is a very elaborate process for determining the shape of the mirrors—lasers, what have you—and of course, since you want this to occur within accuracies of wavelengths of light, and each mirror was built separately to a set of specifications but that the so-called end-to-end test was judged—and again, this will be subject to review as we look at what happened—was judged to not have a good cost-to- benefit ratio. In other words, for the cost of what would be involved and the information learned, that a judgment was made at that time that that was not an appropriate test.

Senator GORE. Is testing of the kind not done on the Hubble normally done for remote sensing satellites prior to their launch?

Dr. FISK. Certainly, the individual instruments are. Perhaps a better case to ask would be AXAF. There will be an end-to-end test on AXAF, the Advanced X-ray Astrophysics Facility. It turns out that in the case of x-ray astron test is, in fact, a fairly straightforward thing to do, and we are in the process today, at this time period, of constructing a facility at the Marshall Space Flight Center whose purpose will be to do an end-to-end test on all the AXAF mirrors together. It turns out that is a $16 or $17 million dollar facility, so in that case there is no question about having a good benefit-to-cost ratio.

Senator GORE. Now, when the military puts optical systems in orbit, or the intelligence community, they are tested prior to insertion in orbit, correct?

Dr. FISK. Senator, quite honestly I have no visibility or knowledge, direct knowledge, of the military systems.

Senator GORE. Well, I am sure you have seen a report in today's "New York Times" that NASA actively considered using the Defense Department's large mirror which it uses to test the sensitivity of intelligence satellites and then rejected the idea. You saw that story, did you not?

Dr. FISK. I read the story, and that is my entire knowledge of the event as well.

Senator GORE. Perhaps some of your associates have some knowledge of what NASA has been doing on this matter?

Dr. FISK. I think unfortunately, though they can certainly speak for themselves, I think in all cases we are more recent additions to the program than the events that would have taken place in the 1980s.

Senator GORE. So you can neither confirm nor deny? You have no knowledge of whether or not the story is accurate, is that what you are saying?

Dr. FISK. That is correct. I have no knowledge.

Senator GORE. Was there anybody in NASA with any corporate memory you could have called on the telephone?

Dr. FISK. I could have, but needless to say I have been running around rather hastily this morning. I read the "New York Times" article coming up in the car.

Senator GORE. What kind of quality control personnel are assigned to monitor projects like the Hubble?

Dr. FISK. Well, again, let me answer this in the context of today, because that I can speak to with some knowledge, and so we will say for projects like Hubble—for example, like AXAF—and as I say, I am not going to try and speak

to the early 1980s—NASA maintains a separate quality assurance organization known as Code Q under the direction of George Rodney. They report directly to the Administrator of NASA and they assign, both in NASA headquarters and at individual field centers, separate quality control people who monitor or participate in all the design and all the construction of our satellites. This is intended to provide an independent oversight which reports neither to the program office, in my case, nor to any other structure within the agency. It gets direct access to the Administrator on quality control issues.

Let me give you some even recent examples. As you know, the decision was made in the Hubble Space Telescope fairly late in the project to use a different set of batteries to provide a longer life on orbit, to use nickel hydrogen batteries as opposed to the original design of nickel cadmium. A review of that was done by me. A recommendation—in fact, a decision was made by me, but the entire process is reviewed independently by the quality assurance people and they provide a separate recommendation to the Administrator—separate from mine—as to whether that is in fact the right decision.

Senator GORE. But is there a group of people charged with routine quality control———

Dr. FISK. Absolutely.

Senator GORE. Assigned to monitor a project like the Hubble?

Dr. FISK. Absolutely.

Senator GORE. How many people are in that group?

Dr. FISK. I will have to get you a number. I do not know. It is in the hundreds.

[The following information was subsequently received for the record:]

There are 1333 civil servants employed by the Office of Safety and Mission Quality. This total includes all personnel reporting to the Associate Administrator for Safety and Mission Quality at NASA Headquarters and at the NASA field installations.

Senator GORE. Well, the quality control personnel within NASA were cut by over 70 percent during the decade preceding this one, beginning in the 1970s. In the aftermath of the Challenger tragedy, hearings before this Subcommittee uncovered that fact. Since the mistakes made in the Hubble were made at roughly the same time the mistakes leading to the Challenger tragedy were made, is it possible that NASA's decision to eliminate 70 percent of its quality control personnel was the common denominator in both failures?

Dr. FISK. Senator, that is certainly something that will be very closely looked at by the review committee. I cannot tell you that. That will depend on, again, what is the nature of the problem. Is it simply some subtle, systematic error that was introduced? Was it an oversight? These are things that when we know the answer to the problem, then we will ask what the cause was and what lessons were learned from it.

Certainly, the testing that you identified earlier, quality assurance that you were talking about now, those are going to be looked at, but I cannot judge that now.

Senator GORE. Now, this morning we are presented with the news that NASA will probably have to undertake a major and complete redesign of important components of the Shuttle system. Again, design errors made during the same period of time when the quality control personnel were cut by over 70 percent. Do you think NASA is ready, given these problems, to undertake major new missions lasting decades with design timetables and construction timetables that will present new possibilities for mistakes to go undetected until launch?

Dr. FISK. Senator, I think we are. Now, I am not going to speak to the agency that existed a decade ago—I was not part of it. But I will speak to the agency that

exists today, and we know what we are doing. Now, any time that you press technology as far as NASA is willing to press it occasionally you fall short. We do not deliberately fall short. We do our very best not to fall short, and I would like to think that the measure of the agency today, as opposed to the measure of the agency ten years ago, is how rapidly, how efficiently, how cost-effectively, we recover from the problems that we have been presented with.

Senator GORE. I accept that answer, but it begs another question. I think the problem is basically that at the present time NASA's eyes are bigger than its stomach. NASA is coming to the Congress time and again with extremely expensive and extremely ambitious projects which excite the imagination of the American people and lead us to dream impossible dreams and give NASA the authority to make them come true.

But as soon as NASA starts to actually implement one of these projects, in order to make room for the next budget request and the next series of ambitious new projects, it goes back and starts taking money away from the people who have been left the unglamorous task of screwing the nuts and the bolts and making the project sound, so that it can actually do what was promised.

I was quoting earlier from the statement by John Rehnberg. This is from an editorial in "Aviation Week and Space Technology" which will appear next week—it is an advance copy—and he says that seven years ago, he said: elimination of development testing due to funding shortfalls, cutbacks on critical support hardware, interruption in certain developmental efforts, general operational inefficiencies.

What that tells me is that the original dream was valid and the hopes invested in this project were properly invested, but then NASA management at that time—not the current managers, but at that time NASA management started cannibalizing the program partly to make room for the ambitious new projects.

Now, the relationship between NASA and the Congress is part of the problem, because there are certain games that get played on both sides. NASA learns from experience that one object of the game is to get the leading edge of the wedge into the budget process. Get the new program underway, and then the funding growth will naturally continue.

Congress then comes back and says, okay, that is fine. We have put out the press releases, we have excited the imagination of the American people, we have encouraged them to dream these wonderful dreams, but now budget reality forces us to spread a smaller amount of money very thinly over all these projects. And that means you have to scrimp and save, cut out the testing if that is what is needed, to save money on Hubble.

Cut out this, and cut out that, but do not interfere with the next dream. Let us go ahead and get started on the next big, extravagant dream, and we will get the start-up funds by cannibalizing the dreams that were announced some time ago but are now in the unglamorous development process. You understand what I am saying, do you not? Do you not think that is a big part of this problem?

Dr. FISK. Actually, in this case I am not sure it is, Senator, and let me express one thought on this. The risk you say is a real one. We always have to be sure that we do not in fact cannibalize, but let us recall a bit of the Hubble history here, and then again my knowledge is almost entirely based on books I have read as opposed to personal experience, but one of the things that was characterized for Hubble was the need for extra money, always, and cost overruns. In fact, I think it is the largest cost overrun of any project NASA has ever had. So I think that the first part of Rehnberg's statement, the technical complexity was underestimated———

Senator GORE. They underestimated technical challenge.

Dr. FISK. Was in fact a valid statement, and perhaps, you know the management—I have forgotten the end of the statement, but it was one about management issues. But the scrimping on money is something we have not done on Hubble. It has come at the expense of other science projects that occurred in the early 1980s.

The trades that were made probably went something like the FOLLOWING. we have an enormous cost overrun here, can we afford to do the testing? But that is a different statement from, we promised them a budget and we took the money out and we gave it to somebody else.

Senator GORE. Well, the money from quality control was eliminated to make room for a lot of new starts. The quality control procedures in NASA, in my opinion, should have been good enough to identify major problems like this one and major problems like the one which led to the Challenger tragedy, and what are evidently major problems now discovered with Atlantis and Columbia. That is my judgment. But we are going to evolve our understanding of it, as you are, with further hearings.

Now in fixing this, what is the likelihood NASA will have to retrieve Hubble from orbit in order to repair it?

Dr. FISK. I think they are remote. Every indication we have at the moment is that the most straightforward repair this is the simple insertion of a single lens or correcting mirror in place of another lens or mirror at the front of the detectors, like the Wide Field/Planetary Camera, which are under development today. They are in the budget. They are scheduled for delivery.

With the June of 1993 on-orbit servicing mission, the only issue we will face is do we want to accelerate that mission. Can we afford to accelerate it? It always costs money to accelerate, but the current budget supports replacement instruments for June of 1993.

Senator GORE. Now someone speculated in an analysis I read this morning that the correction lenses could not be ready in time for the 1993 scheduled launch of the mission.

Dr. FISK. I do not believe that is true, sir.

In the case of WFPC, the Wide Field/Planetary Camera, which is the most impacted of the instruments, the only issue we will face is can we in fact convince ourselves that we have characterized the problem accurately enough to make the lens that needs to be made. But the making of the lens is very simple. And you are probably talking about an item which is in the tens of thousands of dollars, rather than any of NASA's usual kind of costs.

Senator GORE. So, in summary, on the fix required, you are telling us that because it is perfectly and wrong and uniformly wrong, the correction will probably be relatively simple, though time consuming?

Dr. FISK. Only in that we will lose the first few years of the very high resolution, faint object observations, and which we will substitute equally high priority science in the ultraviolet and spectroscopy.

Senator GORE. Well, now, when you say equally high science priority, I guess some in the astronomy community would disagree with that one. I mean we would not have this major disappointment in the science community. And we will hear in just a moment from Dr. Stockman, so I will save that question.

Who is in charge of the Hubble program at NASA?

Dr. FISK. I have the line responsibility.

Senator GORE. All right.

And there have been concerns expressed about the management structure for Hubble, that it was too decentralized, and that there was not enough

communication between the different groups working on it. Do you believe these complaints have validity?

Dr. FISK. Yes. Yes, I do.

And you will notice in projects like AXAF, we do not do that. It is a single-center operation, and the management chain is a lot cleaner. I cannot speak to why people did it for Hubble in the beginning. And I am sure they had good and valid reasons, but I think, in retrospect, it was unnecessarily complex.

Senator GORE. Do you think the problems with NASA's management structure and the difficulties of communication between different elements of the NASA management structure contributed to the problems we now find with the Hubble?

Dr. FISK. Well, again, I believe in doing things sequentially here. And first of all, I need to know where in the process this was introduced. And then I think we will look for causes. And if it turns out—and here I am violating my rule of speculating—but if it turns out that there is some handoff that was supposed to occur of information that led to this problem, then clearly the management complexity would be identified as one of the problems.

Senator GORE. Since the Hubble will not be returning the data it was expected to, will NASA be able to cut operating expenses?

Dr. FISK. No.

And again, I think you ought to ask my colleagues here about the impact of the importance of the science that we are going to do in spectroscopy and ultraviolet. But my measure of the success of the Hubble Space Telescope is how many fundamental new discoveries in astronomy is it going to make. Are we going to uncover the secrets of the universe that we intended to?

And it is my full expectation that over the next few years, while we are waiting for replacement instruments, that you will marvel at the discoveries that are going to come from the observations that Hubble is capable of today.

Senator GORE. You have budgeted almost $200 million a year for the operations of the Hubble, to receive the data sent down, process it, exploit it, et cetera. Now for 1990, 1991, 1992, 1993, we are not going to be getting a major part of that data. The most anticipated data is not going to be available. Are you telling me that we should continue to spend $200 million a year for all those people who were supposed to be working with the data that they are now not going to get?

Dr. FISK. Senator, there is an important point here. Within that $200 million is the cost of the replacement instruments. They are covered under that $200 million.

Senator GORE. Under the operations budget?

Dr. FISK. Yes, operations and maintenance. And so the cost of developing the second-generation Wide/Field Planetary Camera are all——

Senator GORE. What fraction of it is for the people who are designed to receive, process and exploit the data?

Mr. BROOME. About $60 million of that is for the infrastructure for servicing and for development of the new instruments. Another $50-or-so million are truly operations. The rest is bringing along the development and starting the third generation instruments and fine guidance sensors systems.

So it is about half in hardware, a third of the total in operations, and the rest is in building up the ability to do servicing missions, the carriers, the kind of support mission equipment we would need for that.

Senator GORE. Okay.

Dr. FISK. So I think it is important to understand that the bulk of that $200 million is the replacement and——

Senator GORE. Give me those numbers again, $50 million for what?

Mr. BROOME. That is the true operations. It is operating the science——

Senator GORE. $60 million for what?

Mr. BROOME. For the equipment development, the new instrument development.

Senator GORE. And that leaves—a little over $190 million total, that is a $110 million. Where is the other $80 million?

Mr. BROOME. I cannot give you very much more detail below that. But it is to then build——

Senator GORE. Well, $80 million is not a detail in $190 million.

Mr. BROOME. What we have to do is build the carriers to carry the instruments up, to maintain the equipment we have in storage. We have a full inventory of equipment to replace on the Hubble right now that has to be maintained and kept in operable condition.

Dr. FISK. Senator, we will answer for the record the exact detail.

[The information referred to follows:]

The budget estimates for the major areas of Hubble Space Telescope (HST) Operations and Servicing in support of the FY 1991 budget were as follows:

Instrument funding of $55,700,000 in Operations and Servicing funds for completion of the spare wide-field/planetary camera, start-up of second generation instruments, instrument checkout and instrument support equipment.

Flight systems funding of $17,500,000 for completion of the vehicle electrical systems test facility and operations of this simulator, periodic maintenance and test of orbital replacement units, logistics, and development of new orbital replacement units to support the 15-year life-cycle program.

Mission Systems Engineering/Analysis funding of $21,300,000 for systems engineering, servicing planning, mission management, and carrier development and planning.

Mission Operations funding of $26,000,000 for software teams working on both the science planning and mission operations ground systems, the control center team using the mission operations ground system, and telecommunications costs.

Space Telescope Science Institute (STScI) funding of $27,300,000 includes the team which operates the science operations system, develops the software tools to manage the proposal process, maintains data systems, monitors and calibrates instruments, and manages the science program.

Data Analysis funding of $32,200,000 supports Guaranteed-Time Observers, Guest Observers, and continued development of the Data Archive and Distribution Service.

The remaining $11,900,000 funds program support, HST technical support contractors at the Goddard Space Flight Center (GSFC) and Headquarters, multi-program support costs at GSFC, contract administration, and small business innovative research.

Dr. FISK. But I think the point that is important to make here, that if you talk about the actual operations and the science that come from it, it is not the majority of that $200 million.

Senator GORE. Okay. But let us deal with $50 million, then; $50 million is budgeted in each of the next four years to deal with data that is not going to come now. A little of it is, but most of it is not. So are you telling us we should continue to spend $50 million over four years, $200 million?

Dr. FISK. I am telling you that very emphatically. And it would be one of the great tragedies of all time if we were to cut back on the science support of Hubble. Let us be very explicit about this. Hubble is capable of many things. And we have had to make some very hard choices as to what we wanted to do first.

We were a factor of 10 oversubscribed in terms of proposals that came to use the Hubble Space Telescope, that is, a full factor of 10 of quality, high-class, original world-class science. And so we had to make some very hard trades over the time, and we tried to balance between the high resolution faint objects, between the ultraviolet, between the spectroscopy that we were going to do.

And because of the current issue with focus, we are going to be less able to do some, and we are going to emphasize the others. But do not assume that

Hubble is crippled for doing first-class, world-class science, that cannot be done in any other way.

Senator GORE. All right.

What was the original cost estimate for Hubble, and what has been spent so far?

Dr. FISK. I will give you the number I have in my head, and if I am in error in some way, please permit me to correct for the record. It was $450 million in 1978 dollars.

Senator GORE. The original estimate was $450 million. What has been spent so far?

Dr. FISK. Well, I have got an apples and oranges comparison here, because I think I gave you the $450 million was in 1978 dollars, the total real year cost for the development of the Hubble Space Telescope was $1.544 billion. That is the launch plus 30 days.

Senator GORE. And it in 1978 dollars, that would be significantly more?

Dr. FISK. No, it would be significantly less.

Senator GORE. Right.

So it has been roughly a 300 percent cost overrun?

Mr. BROOME. The 1978 dollars would have to be inflated to real year dollars.

Dr. FISK. I think more like 200 percent, but what is 100 percent among friends?

Senator GORE. How much of these cost overruns are due to problems that could not have been anticipated, and how much is just the result of overly optimistic low estimates which nobody believed at the time were right? But they figured they could get OMB and Congress to sign off on them.

Dr. FISK. We would only be speculating on that. I mean that is an analysis that can be done, and perhaps has been done by someone else. I mean you have a combination of two things. The Hubble Space Telescope was originally envisioned to be launched in December 1983. It slipped to 1986, then slipped by the Challenger accident to 1990. And that, in turn, incurred a great deal of the expense.

But that is not to minimize the fact that the telescope for technical complexities, was underestimated at $450 million.

Senator GORE. Now there has been some concern expressed that NASA's over-reliance on contractors is cutting back on NASA's inherent ability to manage things well itself. And recently a letter came to light from NASA's Deputy Administrator, James Thompson, Jr., to the head of OMB, Dick Darman, outlining NASA's concerns regarding the extensive contracting out of the agency. And according to that letter, NASA is worried that OMB's push to "convert more and more critical functions to contractors" is taxing NASA's ability to supervise and manage these large projects it undertakes.

Do you share those concerns?

Dr. FISK. I do. I think that is why you will find in the fiscal year 1991 budget, that NASA placed its highest priority on the funding of personnel, because of the sense that the agency is in need of quality people to undertake the very tasks that we are undertaking.

Senator GORE. You were saying a moment ago about the science that really there is a lot of great stuff that can be done.

Dr. FISK. Absolutely.

Senator GORE. Well, Mr. Weiler, what is your position in the—your formal title, again?

Dr. WEILER. I am the NASA headquarters Program Scientist for Hubble.

Senator GORE. You were quoted as saying. "There is no real science we can do with it at this time."

Dr. WEILER. That is the WFPC I was talking about.

Senator GORE. Okay.

Dr. WEILER. And that was based on the principal investigator's 12-hour analysis of this problem.

Senator GORE. So that instrument is—that is the one that gives us visual images.

Dr. WEILER. That is correct. The WFPC is not a good ultraviolet camera. It is an excellent visible camera. The faint object camera, however, the European camera can work in the ultraviolet, and it will be used to take many, many images in the ultraviolet.

Senator GORE. Okay. Let me shift gears right now and ask Dr. Hervey Peter Stockman from the Space Telescope Science Institute to give us your analysis, Dr. Stockman, and then we will talk a little more about the impact on the science.

STATEMENT OF DR. HERVEY PETER STOCKMAN, DEPUTY DIRECTOR, SPACE TELESCOPE SCIENCE INSTITUTE

Dr. STOCKMAN. First, I would like to thank the Chairman for giving me the opportunity to address——

Senator GORE. Move the mike a little closer, if you would.

Dr. STOCKMAN.—to address the Space Subcommittee. As the Deputy Director of the Space Telescope Science Institute, I am pleased to provide a preliminary appraisal of the science mission of the Hubble Space Telescope in light of the optical measurements made over the last month, and the analyses which have been made of those measurements, in which Institute staff have played a major role.

At the outset, I would like to emphasize that many of the primary scientific goals of the Hubble Space Telescope can still be accomplished, even with the imperfect images which have been achieved to date. These lie principally in the areas of ultraviolet spectroscopy, imaging and photometry, where the observatory's performance is only moderately affected.

One of the key scientific projects which was identified by the Space Telescope Advisory Committee several years ago, the study of intervening gas in galaxies by its absorption of ultraviolet light from distant quasars, falls into this category of science. Also for a certain class of imaging, involving high contrast objects of moderate brightness, the sharp core of the images observed with the Faint Object Camera provided by the European Space Agency and the wide-field planetary camera can be exploited to obtain nearly diffraction-limited images to address important morphological questions, such as the cores and spiral arms of galaxies and features on planetary atmospheres.

However, it is true that many critical scientific goals cannot be accomplished with Hubble in its current state. These lie primarily in the area of faint visible imaging, or deep imaging within crowded or complex fields. Two of the key projects fall into this category: obtaining the distant scale of the universe by observing faint clusters of stars in distant galaxies and deep surveys of the sky to discover new objects and obtain statistics on distant galaxies and their types. Also, looking at and exploring the faint environments around distant quasars and nearby bright stars has been greatly compromised.

We at the Space Telescope Science Institute have initiated a review of the general observer science programs which have been approved for the first year of routine science operations. Our preliminary analyses indicate that 50 percent of the current program remains viable. Based upon the results of this review, we will adjust the program accordingly.

In the meantime, we will communicate the technical information which we have obtained and which is given to us by NASA, to the scientific community.

In considering the scientific objectives which cannot be achieved with the current imaging performance, we at the Space Telescope Science Institute are heartened by two facts. One, the Hubble Space Telescope is healthy, with all five scientific instruments and the fine guidance system passing their initial commissioning tests. Two, the nature of the current optical program problem appears to allow for the complete correction of the problem in the second generation scientific instruments currently under development. In particular, we at the Space Telescope Science Institute strongly recommend to NASA that, following the report of the review board and further optical tests, they proceed with the necessary modifications to the Wide-Field Planetary Camera replacement now in construction at the Jet Propulsion Laboratory and the two advanced instruments, and that these modified instruments be installed in the telescope by shuttle servicing at the earliest possible opportunity.

We look forward to doing outstanding work with the Hubble Space Telescope in its present condition during the next few years. And we also look forward to accomplishing all of the goals of the full Hubble mission, including the two deferred science projects mentioned earlier, during its planned 15- year lifetime.

Senator GORE. The images that can be received are ones in ultraviolet and what else?

Dr. STOCKMAN. Well, all the instruments appear to be working satisfactorily and to their specifications, so we can receive the images on all of the instruments. In fact, we could observe the fields that were planned to be observed for the periods of time that they were planned.

It is likely, however, that in many cases those observations, due to the optical quality of the telescope, would not be sufficiently superior to those obtained under excellent conditions at ground-based sites that it would be appropriate to do those science programs. And we anticipate having to modify those programs and bring up spectroscopic programs or imaging in the ultraviolet light, which cannot be done by any observatory at the moment, into the first two years of scheduling.

So the answer, I think, is that the data can and will come in from all the instruments. It is just that in order to maximize the scientific return of the satellite we will be taking less visible pictures.

Senator GORE. Well, let us exclude images that are no better than what you can get from earth-based, ground-based telescopes. Let us eliminate all the images that are no better than what you can get from ground-based telescopes.

Then what else is going to be received that is of value? You have the ultraviolet.

Dr. STOCKMAN. Well, we have ultraviolet imaging——

Senator GORE. Yes.

Dr. STOCKMAN.—which has resolution, even ignoring the sharp cores in these images, which is comparable or better than, say, the average ground-based large telescope, and, of course, because it is in the ultraviolet, it is unique. It allows the study of newborn star clusters and galaxies. It allows the study of hot gas. It allows the study of newly- forming galaxies very far away and long ago. So I anticipate there will still be a very rich science program in that area.

Senator GORE. Now, that relies on the same mirrors; it has the same distortion of focus. But even with that distortion of focus, the ultraviolet images will be more useful than those obtainable from the ground, because you are——

Dr. STOCKMAN. Basically, you are working in a different wavelength.

Senator GORE. Above the atmosphere.

Dr. STOCKMAN. That is correct. Secondly, important observations can be obtained in the visible for high contrast objects and for objects which are bright. Many of these objects are in our program, but because they are bright, they take relatively little time. With addition of a bit more time, we can take those images and deconvolve them using digital techniques and recover practically the resolution we anticipated to recover with the original space telescope.

That at the moment is not the majority of the planned imaging program, because——

Senator GORE. It is a lower priority?

Dr. STOCKMAN. Not so much that. Since these targets are bright and the data is quickly taken, these observations take relatively little time. Secondly, it is true that the initial peer review of these programs had the philosophy that the science that would be taken during the first year of Hubble Space Telescope should be the most critical science which was then on the table and which should be accomplished early in case the Space telescope were to have any problems in the future.

So the most difficult scientific programs were put forward—the ones which relied on the Space Telescope having the specified characteristics and would be perhaps susceptible to degradation. So I think it is fair to say that those programs, naturally, have suffered because of the image quality we currently have.

Senator GORE. Are you now beginning the process of redesigning your priorities for the next three or four years?

Dr. STOCKMAN. Yes, sir.

Senator GORE. How long will that take?

Dr. STOCKMAN. Well, as I said, we are beginning the analysis of the initial impact. Currently, we are establishing a rough estimate of 50 percent of the program being viable based purely on instrument utilization, the fact that the spectrographs are used more than 50 percent of the time in the current program.

But more in-depth analysis will need to be made over the next two months, culminating approximately at the time when think the optical quality is better known, and the initial reports, perhaps, of the review board have been received. At that time, we will know the telescope characteristics and the prospects for even minor improvements over the next two years.

At that time, it is our plan to reconvene a portion of the original peer review panel. We will provide them with analyses of the programs as we see them technically. They will re-review the program and recommend changes in priorities to emphasize those projects, most of them already approved, which can be done with the Space Telescope and achieve their original goals.

Senator GORE. Now your Space Telescope Science Institute works for NASA? How would you characterize the relationship?

Dr. STOCKMAN. We are a part of the Association of Universities for Research in Astronomy, a consortium of universities which has a contract with NASA.

Senator GORE. I see. So you have a contract with NASA. There is no way to put a dollar value on the amount of the science lost, is there?

Dr. STOCKMAN. I think that is a fair statement.

Dr. FISK. I would like to say, Senator, I do not think it is lost; it is just deferred.

Senator GORE. What is the design life of Hubble?

Dr. FISK. 15 years.

Senator GORE. 15 years.

Dr. FISK. With on-orbit servicing. That is why there is a whole set of what are called orbital replacement units, ORUs, that are maintained on the ground. If some critical subsystem fails, we plug a replacement unit it and fix it.

Senator GORE. So three to four of those 15 years are lost?

Dr. FISK. No. Again, I mean, you are going to see a sort of relative priorities here. I mean, you have a situation where the WFPC will be less used during the first three years.

Senator GORE. I understand. But the research that they are really most interested in is not going to be available for three or four years.

Dr. STOCKMAN. Senator, may I add a comment in that regard?

Senator GORE. Yes.

Dr. STOCKMAN. I think that Dr. Fisk is right in saying that there is plenty of science in the program which we have received for the first year of observing to run for the first several years in this condition—top notch science. We were oversubscribed by a factor of 10; and that was in the first submission, where people were submitting scientific programs to compete with each other in the arena where this telescope had its stated characteristics, and in which the imagination of the scientists and their ability to cope with this data and to maximize their benefits in this condition did not come into play.

So I believe that, indeed, until the next servicing mission we will have no problem meeting the major goals of Hubble Space Telescope in these areas.

Senator GORE. How many scientists, Dr. Stockman, would you estimate have planned out their work schedules based on the data expected to come from Hubble?

Dr. STOCKMAN. In the General Observer Program, there are 162 programs with approximately 120 different principal investigators, who are the dominant scientists and then approximately 500 in total, if you include co-investigators, for which this was an important but not necessarily the only portion of their scientific plans for the next two years. So approximately 500-600 scientists are affected, including the Guaranteed Time Observers, the scientists that have been with the program since its beginning.

Senator GORE. Well, I certainly feel for those who have experienced the delay which came in the Hubble launch after the Challenger disaster and now this other delay. There are a lot of distinguished scientists who have planned their lives around this project, and now this further delay is disappointing them again.

We are going to finish up here fairly quickly. Let me ask you about other problems with the Hubble. Dr. Fisk, and Dr. Stockman, please feel free to comment if you wish, "Science Magazine" had an extensive article last year on problems with the software for controlling the Hubble as well as allocating observing time. The cost overruns and delays involved in developing that software appeared ridiculous. It seemed that everything that could go wrong did go wrong. Are you familiar with that software problem, and has it been fixed?

Dr. FISK. Things are being fixed very rapidly. We have no issue that we are working that we think will interfere with the operation of the Hubble Space Telescope.

Senator, I know that you are aware that when you fly something this complex you anticipate a learning curve. That is why you build safe modes in. That is why we put orbital verification periods in, and the Hubble was really not unusual in its experience compared to other projects that NASA and other space agencies have flown. We did this one a little more visibly, perhaps, than others.

I hasten to remind you that as we went to Venus with Magellan we spent a fair amount of time in safe modes and things. While we took the bugs out of that, no one cared, particularly, because they were waiting for us to get to Venus and they were not watching. This one, everyone watched.

But I think the important thing is that we know of no problems at the moment, other than the spherical aberration that cannot be completely corrected for and reach full specifications.

Senator GORE. Has the software problem been solved?

Dr. FISK. The software problem has been solved. The only one that still remains to be implemented software change for the ''jitter" in the telescope as it crosses from day to night, and that is, we believe, completely correctable, but it requires some fundamental changes in some of the software and we are implementing those changes over a period of months.

Senator GORE. What about the problems in pointing the antennas?

Dr. FISK. Oh, those are behind us remember, there are two high-gain antennas, one of which has evidently broken if this model is valid, and one is down here. One of them works without any difficulty whatsoever. The other one had a small portion of its rotation blocked by a cable, and we have simply programmed it so that it does not go into that region; the impact on science is nonexistent.

Senator GORE. Again, one other question on the implications this has for other NASA programs.

Just last week, in the June 19 "New York Times," there was an article reporting that many scientists are asking whether NASA's planned Earth Observing System (EOS) might not be too big, too costly and too vulnerable. As you know, I am a very strong supporter of NASA's Mission to Planet Earth, and EOS is a key component of that mission. As a matter of fact, we just authorized a new start for EOS two days ago in this Committee. But in light of the problems with the Hubble, I am concerned when I hear prominent scientists questioning whether EOS might not work as planned.

A few months ago at a Subcommittee hearing we heard testimony about a National Research Council report on EOS. The scientists writing that report felt that at least half of EOS' mission could be done with smaller satellites which do not pose the same risk of losing the whole system due to an accident or undetected design flaw. In addition, at least some of the satellites can be launched sooner.

I am sure that you expect to experience even closer scrutiny of EOS in light of the problems with Hubble. Is NASA likely to reassess its plans for EOS in order to minimize the possibility of another problem like the one we are experiencing with the Hubble?

Dr. FISK. Let me make a few comments, because I think we ought to all be clear on something. First of all, we have always been in agreement on the Academy's report that said there is a compelling argument for having the first platform series be a large platform series and the argument for the second platform series is not scientifically compelling, but we need to make it on engineering and programmatic grounds, and that has been NASA's position.

But let us be clear here. I mean, whether or not you are on large platforms or small platforms is not a parallel with the Hubble issue. EOS is made up of a series of individual instruments. There is no single, optical system that goes in EOS, and the technical challenges come in the design of the individual instruments.

Whether or not they are on big platforms or little platforms is not pertinent. The question is, can we build all these instruments that we intend to build? I think you would find that the scientists en masse would argue that each and every one of the instruments that we plan to fly needs to be flown, because it identifies some of the critical aspects of the global change program, and in all cases those instruments are a direct heritage of previous programs.

The most relevant experience prior to EOS for that program is not something like Hubble, it is something like the Upper Atmospheric Research Satellite (UARS), which has about the same number of instruments. There is about 30 percent less weight involved, and I think you will find that we have had, first of all, no management difficulties with UARS. It has been under budget

consistently, and we are on schedule for launch, and I have anticipation that it will be a highly successful program.

Senator GORE. Do you think this incident is important in the debate over big science versus small science? Opponents of big science will, of course, use Hubble as another example of why research dollars are in their view better spent on more modest, less grandiose projects, arguing that as the complexity of a system increases the probability of serious problems goes up exponentially, whether you are talking about satellites or some other piece of equipment.

Dr. FISK. Senator, I am sure we are going to have that debate, but this is something I feel quite strongly about. You know, whenever you object to big science, as they are categorizing it, you are really also, in this context, objecting to the advance of science, because it was generally decided by the science community in the 1940s, 1950s and so forth, that in order to make advances in optical and UV astronomy, you needed a bigger telescope.

I mean, it is really that simple, that we had exploited things like International Ultraviolet Explorer (IUE) and Orbit Astronomical Observatory (OAO)-type satellites what could be done from space with small telescopes, and we needed to move on to the next generation.

Ironically, you know, the problem we are having with Hubble is not its complexity. This is in many ways the simplest part of the system, which was to construct a physically large mirror. I mean, we should bear in mind that the fine guidance sensor ability to point the telescope with incredible accuracy for a long period of time is working perfectly.

Senator GORE. The part that does not is the same kind of thing that Galileo did when he created the first telescope.

Dr. FISK. I am sure his telescope had spherical aberration, though, but he probably did not notice.

Senator GORE. But it is an extrapolation of the basic task.

Dr. FISK. I need to add, one of the reasons we are very puzzled as to how this occurred, and we are all going to be very interested in the answer when it comes out, assuming we can get a definitive one, is because we did not expect this to be part of the problem. We expected to have a challenge in building a really smooth mirror. Well, we did that. It is perfectly smooth. We did not anticipate having any difficulty in the curvature of the mirror. That is a very routine part of any optical system, and one that is done on the ground for any optical system, so the complexity of Hubble is not our issue here.

Senator GORE. Of course, serious problems are often by definition the unexpected ones, and that is why, in conclusion, I come back to the issue of quality control as the common denominator between the Hubble failure and the Challenger failure, and perhaps the Atlantis problem discovered today. I hope that this problem can be solved. The mirror anomaly I hope can be solved as well.

We intend to pursue this matter vigorously. We have been assured for 12 years now that everything was under control and everything was fine, and as a result we were justified in allocating the taxpayers' money, to give it to NASA and get this thing up into orbit. Now that this mistake has occurred, we owe it to those same taxpayers to find out not only exactly what went wrong but how to fix it, and how to make sure it does not happen again, otherwise we cannot go back to those taxpayers and say we want a lot more money to trust NASA to do even more complex, more expensive things in the future.

Now, as we continue examining this in July, I take it from our earlier discussion you do not have any problem appearing in the same hearing with the contractors, is that correct?

Dr. FISK. I certainly do not now.

Senator GORE. I am sure that a subpoena will not be ultimately necessary to get the contractors to come, but just in case we are going to set in motion the procedures to make it possible to issue one, if it has to be. I do not think that is going to be necessary.

Dr. FISK. Senator, it will not be necessary.

Senator GORE. Well, with that we look forward to talking with you again in July as we continue our investigation of this.

Thank you very much.

[Whereupon, at 11:21 a.m., the subcommittee adjourned.]

[The following information was subsequently received for the record:]

SPACE TELESCOPE SCIENCE WORKING GROUP

SIXTH MEETING

14-15 DECEMBER 1978

BUILDING 21, GODDARD SPACE FLIGHT CENTER

MEMBERS PRESENT	MEMBERS ABSENT	OBSERVERS
J. N. Bahcall	None	W. C. Keathley, MSFC
R. C. Bless		J. B. Martin, GSFC
J. C. Brandt		I. R. King, AAS
J. J. Caldwell		S. L. Jones, GSFC
W. C. Fastie		J. W. Keller, HQ
E. J. Groth		J. R. Olivier, MSFC
R. J. Harms		A. Reetz, HQ
R. W. Hobbs		A. Rohrkemper, LMSC
W. H. Jefferys		A. Davidson, JHU
D. L. Lambert		R. Moore, GSFC
J. F. Leckrone		
M. S. Longair		
F. D. Macchetto		
C. R. O'Dell (Chairman)		
N. G. Roman		
D. J. Schroeder		
H. J. van de Hulst		
J. W. Warner (Secretary)		
J. A. Westphal		

The meeting was called to order at 9 a.m., C. R. O'Dell presiding. The agenda (enclosure 1) was circulated and several additions made. Several corrections were made to the previous minutes. King felt that they had not reflected the strong sentiment expressed by the Working Group in favor of the 8M bit storage for the FOC. Groth suggested inserting the word "serendipity" between "preclude" and "use" (p. 4, lines 7-8) so as not to imply that only the WFC will be used for this purpose. He also mentioned that CODMAC (p. 5, line 11) was a committee of the National Academy of Sciences Space Science Board.

RECEIVED

O'DELL gave the report of the Project Scientist. In the interim period since the last meeting, the Science Operations Concepts document was prepared by the Project Office and sent to Headquarters for approval. Upon approval, it will be sent to all SWG members. A presentation on the ST Science Institute was made to the Hornig Committee of the National Academy of Sciences on November 2-3. Work on the preparation of the Science Institute Request for Proposal (RFP) has intensified, and discussions with the ESA representative (Macchetto) have clarified the ESA role in the Science Institute procurement process. Finally, two video tapes were prepared which describe the ST project and may be available for public viewing.

JEFFERYS gave a report of the Astrometry Team. Franz has studied the probability of unresolved binaries being chosen as guide stars with the preliminary result that 12-15% of all candidate guide stars could cause problems. The opinion of the SWG was that we must have a solution to work around the problem, for example, ground-based observations to sort out problem stars and, more important, the capability to store backup guide stars. Astrometry documentation is becoming more complete, and the Astrometry Team Leader would like comments on the guide star selection requirements document. He gave a short discussion on astrometry requirements for various types of target sources (enclosure 2) and showed potential proper motion errors for various combinations of existing plates. He suggested that a resurvey of the northern sky might be appropriate, at least in those cases where accuracies better than one arc second were required.

GROTH gave the report of the Data and Operations Team. The DOT is establishing a list of concerns which is currently up to 35 items. He gave a short report of the Mission Operations Working Group meeting in which off-line data processing and targets of opportunity were discussed. The DOT meeting emphasized discussion of operations requirements. The DOT Leader's opinion was that real-time operations of the spacecraft must be available to implement data monitoring, target acquisition, instrument parameter adjustment, and preplanned branches. Keathley reminded the group that there would be SI C&DH software limitations. Roman asked what percent of time that real-time operation would be necessary and what was the response time required, to which Groth answered: approximately 20% real-time operations and 1/2 an orbit response time.

3

HARMS reported on FOS activities (enclosure 3). Decisions were made which resulted in increased resolution with a subsequent loss in limiting magnitude (10%). Several new methods of measuring polarization were under active discussion. The complement of entrance apertures was finalized. A new method to produce cathodes which should avoid the Cesium migration problem encountered by the FOC was being tested. Some significant progress was made on HRS-FOS commonality.

BRANDT raised the question of SWG participation in the OTA and SSM PDRs. O'Dell responded that Fastie and Schroeder would represent the group at OTA PDRs and that the full group was invited to the SSM/OTA systems review. Brandt demonstrated a model of the HRS.

WESTPHAL reported on Wide Field Camera activities (enclosure 4). Recent work on UV filters using potassium and sodium has produced combinations giving good UV transmission and good long wavelength rejection. He then presented results of tests on a transmission grating which showed excellent blaze and transmission characteristics. He mentioned the satisfactory peel tests on the CCD coatings. A ground based CCD system was tested at Mt. Lemmon with good results. He described the filter wheel, filter selection problems and the current situation on power constraints.

MACCHETTO related FOC development (enclosure 5). Decisions were made to retain the 4M bit storage and to fly an f/48 spectrographic model. They are working on the unique science drivers for each individual observing mode. He described the status of the camera module. Problem areas included power and the detailed thermal design. Major changes regarding the cathode include the choice of a hot bi-alhalii (SbKNa) design which does not require a cooled photocathode but means a subsequent drop in the red response (lower by a factor of ten, but it still meets the NASA specification). Clear gains in sensitivity were made in the ultraviolet, as a comparison of speed with the WFC showed.

BLESS reported on FOS preparations for PDR. The electronic design was in good shape and the low/high voltage power supply was out for bids. The results of negotiations with ITT on detectors was unsatisfactory; as a result, they are considering more inhouse work. A mechanical analysis carried out using aluminum showed it to be satisfactory for the basic structure.

HARMS presented the current baseline specifications (enclosure 6) on his long wavelength detector as well as the results of recent thermal studies. A new thermal design which would insure the red response, considered important in the past by the working group, would cost $325 K. A discussion ensued as to what fundamental information was needed in order to make an informed decision. It was concluded that the information was not immediately available, and some work was still required. A further discussion occurred the following day at which Bahcall and Harms gave the results of an example calculation concerning how many more red shifts could be determined if an extra 500 angstrom sensitivity were available. Both concluded (enclosure 7) that the increase in science was marginal compared to what could be expected from ground-based work in the same wavelength region.

OLIVIER presented a summary (enclosure 8) of the current power and thermal situation including the definitions of the hot and cold cases, the five different power modes, power constraints, the effective sink temperature distribution and the safemode gravity gradient aft shroud temperatures. He stated that a broader definition of serendipity would not affect the thermal situation as long as the upper limit of 475 watts was adhered to. A potential problem was that some instruments may not be able to attain the hold limit of 37 watts.

O'DELL restated the current baseline definition of serendipity as "WFC +1" and explained the need for baselines within the project, the major driver being the need to save both time and money. He stated that ultimately the goal must be to maximize the science, and that serendipity would finally be an operational decision. The resulting discussion revealed several areas of concern including (1) whether we are limiting our science by forcing SIs into untenable hold modes (Leckrone), (2) the policy under which serendipity would be administered (Groth, Westphal), (3) the need for two axial SIs to be operating simultaneously (Roman), and (4) the problem of calibrating instruments.

LEVIN described the forthcoming PDR milestones, the review board membership and the elements of the SI office report to the project (enclosure 9).

LAMBERT presented some thoughts on ground based observing requirements which were put together with Longair. Ground calibration was in reasonable shape but would need to be supplemented by on-orbit calibration. Positions of guide stars known to an accuracy of $\pm$ 0.3 arc seconds would suffice for all but the small FOS aperture. Deficiencies mentioned

by Benedict (guide star selection system requirements) suggest that new plate material would be necessary for approximately 20% of sources but that this could be accomplished using a reasonable amount of 48 inch Schmidt time (~1 month/year). He suggests waiting for the final astrometry report, as there would still be sufficient time to begin a program. A calculation of the amount of 4 meter observing time necessary to support exceptional objects to be observed by the FOS (~10 objects/year) suggested a small number of nights would suffice, and it would be valid to support such a program. Fast moving objects and asteroids need special attention. Some concern was expressed as to whether enough measuring machines were available to handle the guide star selection requirements. No consensus existed supporting the building of a dedicated ground-based telescope to support ST. Some ideas brought up by the group were: (1) the Hale 48-inch could be used during grey time; (2) less formal organization to meet the problem was necessary; (3) for faint objects, improved instrumentation would be necessary; (4) there existed a potential problem with UV standards, a UV survey might be necessary; (5) most observers felt it their own responsibility to support their own ST research.

KEATHLEY described the current status of the primary mirror blank and the work in progress to relieve several areas where the edge band was adhered to the inner supports. Progress on polishing the 60-inch blank was quite satisfactory.

MOORE (GSFC) presented a description of the TDRSS system and its application to the ST (enclosure 10). Constraints determined by solar noise, the Earth's shadow, Soviet radar interference, positioning of the High Gain Antenna and up- and downlink availability were mentioned. TDRSS scheduling requirements and consequences for real-time operations were discussed. Dick Moore's phone number is 301/344-7815 (FTS 344-7815).

MARTIN summarized the study of operations planning (enclosure 11). Major milestones included a presentation of science operations concepts to the Hornig Committee and an operations functions document to the DOT and the Mission Operations Working Group. The Science Operations Concepts document will be distributed to SWG members in January. He summarized the major items of discussion at the Hornig Committee. No official report from the committee had been received. The issue of "core staff" for the institute was discussed with the Hornig Committee and was further discussed in the SWG. The major issue was the fact that in NASA planning the scientists were assumed to be connected intimately with operations rather than wholly concerned with

their own research. Martin and O'Dell assured the committee that the staff was sized such that there was wide latitude available to the ScI director on the issue. Martin discussed key dates in the ScI procurement schedule. O'Dell reminded the committee of the constraints on the material being presented, as official approval had not been given. Any future information provided would be official and widespread in its release. The necessity for total conformity to legal government procedures was emphasized. Caldwell questioned the judgement of NASA's publishing the IAU proceedings on ST to be held at Princeton, a potential bidder. O'Dell promised to look into the question but felt that the event was important enough to justify NASA support. Van de Hulst raised the question of the role of the SWG in the transition-to-operations phase and was told that this would be part of the RFP.

BLESS discussed object acquisition with the HSP. They could do blind pointing and on-board centering in a one arc second aperture for objects with well known positions. For objects with poor positions, a ten second aperture would be used for finding and subsequent geometrical offsets calculated. No pattern recognition was planned; but, if problems occurred, a 10 x 10 second map could be made, displayed on the ground and interacted with in real time. TDRSS contact time would have to be considered in such a case.

BRANDT discussed object acquisition with the HRS (enclosure 12). Their mapping mode in a 2 x 2 arc second aperture provides them with on-board centering to ~1/8 arc second accuracy in a time of four seconds. For a case in which the star is not in the slit, 8 more maps could be made in times of the order of several minutes. Ground interaction would be necessary to center the source. The problem of extended and moving objects had not been addressed as yet. Close binaries of equal magnitudes would present problems.

HARMS discussed object acquisition with the FOS (enclosure 13). His method was similar to that of the HRS. In addition, blind pointing using positions generated from ground-based or WFC pictures might need to be used. Their on-board centering procedures were soon to be time consuming for faint objects, approaching 10% of the exposure time. Offsets could be made from bright stars.

KEATHLEY presented the project's plans for assembly and verification and showed a typical waterfall diagram (enclosure 14). He described the points of interaction of the principal investigators with the A&V process. No calibration, which could not be accomplished by external control, was planned after integration. No thermal vacuum test was planned for the full ST, only for the subassembly levels. Pre-integration thermal vacuum tests would be allowable, as determined from requirements. It is physically impractical to demonstrate the telescope's performance on the ground. Sufficient subsystem tests and analytical performance models would be run to achieve the equivalent. He described the OTA site and testing sequence, the SSM A&V and the total ST level A&V including procedures at the Cape. A purge for the instruments would be provided, but the system would not be flown. It would be disconnected 24-48 hours before launch.

O'DELL set the next meeting on February 20-21, 1979 at Goddard. The May meeting was temporarily cancelled, and it was to be decided in February whether to have another meeting before June. The next scheduled SWG meeting will be on June 20-21 at MSFC, the two days following the SSM PDR, which individual members may wish to attend. All SWG members were invited to the forthcoming SI PDRs.

NOTE: An addendum to these minutes includes (enclosure 15) a copy of a letter from the ST Project Manager, W. C. Keathley, to Professor Westphal regarding the project position on data rates. In addition, a statement (enclosure 16) by Groth and Longair regarding their reservations concerning the change in FOS red sensitivity is included.

SPACE TELESCOPE PROJECT RESPONSIBILITIES

MARSHALL SPACE FLIGHT CENTER
- PROJECT MANAGEMENT
- ORBITAL MAINTENANCE

LOCKHEED MISSILES AND SPACE CO.
- SPACE TELESCOPE SYSTEMS ENGINEERING AND INTEGRATION
- SUPPORT SYSTEMS MODULE DESIGN AND DEVELOPMENT
- SPACE TELESCOPE ASSEMBLY AND VERIFICATION
- SPACE TELESCOPE LAUNCH AND ORBIT VERIFICATION

GODDARD SPACE FLIGHT CENTER
- SCIENTIFIC INSTRUMENTS
- COMMAND AND DATA HANDLING SUBSYSTEM
- SPACE TELESCOPE MISSION CONTROL CENTER AND SCIENCE OPERATIONS
- SCIENCE INSTITUTE

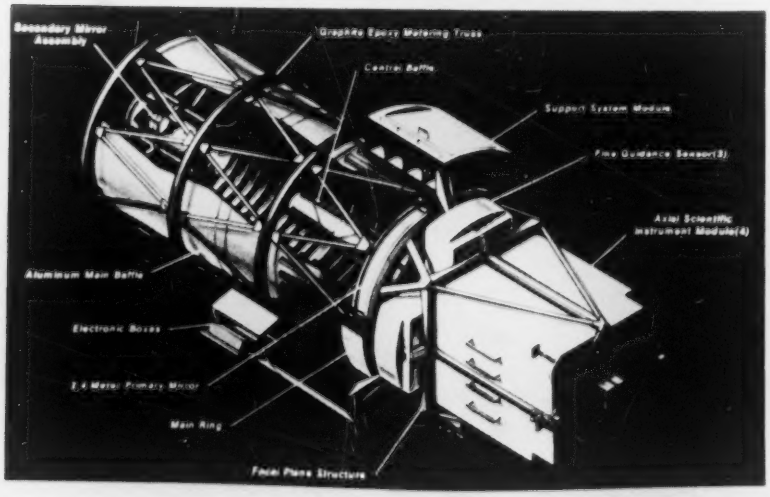
JOHNSON SPACE CENTER
- SPACE TELESCOPE - ORBITER - CREW INTERFACE AND OPERATIONS

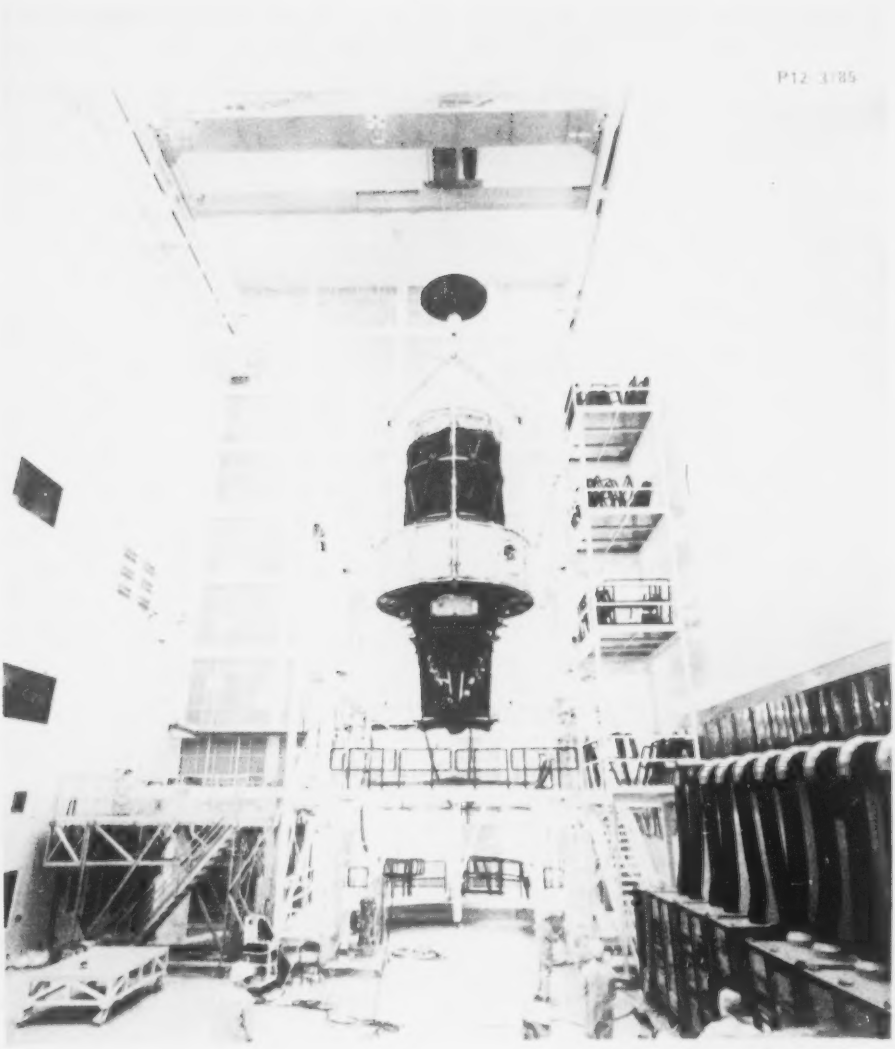
PERKIN-ELMER
- OPTICAL TELESCOPE ASSEMBLY DESIGN AND DEVELOPMENT
- FOCAL PLANE ASSEMBLY SYSTEM ENGINEERING
- FINE GUIDANCE SENSOR

EUROPEAN SPACE AGENCY
- SOLAR ARRAY
- FAINT OBJECT CAMERA
- SCIENCE INSTITUTE PARTICIPATION

KENNEDY SPACE CENTER
- SPACE TELESCOPE - ORBITER LAUNCH OPERATIONS

CROSS SECTION OF THE HUBBLE SPACE TELESCOPE

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ATTACHMENT I

NASA-WIDE SRM&QA STAFFING TOTALS

CIVIL SERVICE	1986	1987	1988	1989	1990
HQ	33	64	64	73	78
JSC	159	170	195	210	210
KSC	212	260	280	399	399
MSFC	107	180	235	235	245
SSC	7	8	8	8	10
ARC	33	35	37	39	39
LaRC	62	62	61	63	62
LeRC	72	90	84	91	103
GSFC	160	163	165	178	187
TOTAL CIVIL SERVICE	845	1,032	1,129	1,296	1,333
JPL WORKFORCE	228	258	264	279	279
SUPPORT CONTRACTOR	711	971	1,198	1,477	1,453
MAJOR CONTRACTOR	N/A	3,165	3,877	3,961	4,095
DoD	438	438	438	438	438*
TOTAL	2,222	5,864	6,909	7,451	7,598

* PRELIMINARY – UNDER DISCUSSION WITH DoD

ATTACHMENT II

APPROXIMATE NASA SRM&QA FUNDING

(MILLIONS)

	FY 88	FY 89	FY 90
CIVIL SERVICE	54	61	65
JPL WORKFORCE	14	16	16
SUPPORT CONTRACTOR	83	102	104
MAJOR CONTRACTOR	267	268	334
DoD	30	30	30*
R&D SPECIAL PROJECTS	6	6	6
CODE Q R&D	14	22	23
TOTAL (SRM&QA)	$468	$505	$578

* PRELIMINARY – UNDER DISCUSSION WITH DoD